Géographie physique et Quaternaire

# Late Quaternary Marine and Terrestrial Environments, Northwestern Baffin Island, Northwest Territories

# Environnements marin et terrestre du Quaternaire supérieur, dans le nord-ouest de l'île de Baffin, Territoires du Nord-Ouest

# Meeres- und Landumwelt im späten Quaternär im Nordwesten der lnsel Baffin, Nordwest-Territorien

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Résumé de l'article

On a procédé à l'analyse des données paléoenvironnementales tirées de sédiments terrestres, marins et lacustres, près de Arctic Bay. Dix-huit nouvelles dates au radiocarbone ont permis d'établir une nouvelle chronologie. Les dates les plus anciennes, et les moins fiables, ont été obtenus dans des tourbes sableuses et des sédiments lacustres à basse teneur organique. Les dates les plus sûres proviennent de coquillages marins et des foraminifères. Elles indiquent que la déglaciation était en cours dès 9000 BP plutôt qu'à 16 000 BP. Pendant la période relevée, l'environnement dans le haut Arctique était caractérisé au niveau local par un assemblage pollinique dominé par l'herbe, le carex et le saule; à l'Holocène moyen, les valeurs croissantes du saule, de l'herbe et de la mousse reflètent une période chaude. La densité de la glace marine était assez forte pour empêcher la croissance des diatomées jusqu'à 6300 BP; la déglaciation s'est poursuivie jusque vers 6000 BP dans les fjords. La reproduction des diatomées a augmenté entre 3000 et 2500 BP en raison de températures de surface plus chaudes et une diminution des glaces marines. Après 2000 BP, l'accumulation des diatomées a décru abruptement en raison d'un refroidissement climatique. Les foraminifères démontrent un changement important survenu dans l'état des eaux profondes vers 4000 BP puisqu'il y a eu remplacement des espèces benthoniques à test calcaire par des espèces à test agglutiné.

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# LATE QUATERNARY MARINE AND TERRESTRIAL ENVIRONMENTS, NORTHWESTERN BAFFIN ISLAND, NORTHWEST TERRITORIES

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ABSTRACT Paleoenvironmental data were analyzed from terrestrial, lake, and marine sediments collected near Arctic Bay, Baffin Island, N.W.T. Eighteen new radiocarbon dates provide chronological control, superseding earlier results. Spuriously old dates were obtained from both sandy peats and low-organic lake sediments. The most reliable dates were from marine shells and foraminifera. They indicate that deglaciation was underway by 9000 BP rather than 16,000 BP. Over the period of the record, the local environment was characterized by a high arctic pollen assemblage dominated by grass, sedge, and willow; a middle Holocene warm period is indicated by increased willow, herb, and moss values. Sea-ice conditions were severe enough to inhibit the growth of diatoms until *ca.* 6300 BP and ice proximal and deglacial conditions prevailed in the fiords until *ca.* 6000 BP. Diatom productivity increased between 3000 BP and 2500 BP, suggesting warmer surface waters and less sea ice. After 2000 BP diatom accumulation decreased sharply, due to a cooling of climate. The foraminifera indicate a major change in bottom water conditions *ca.* 4000 BP as the benthic species shift from a calcareous to an arenaceous assemblage.

RÉSUMÉ *Environnements marin et terrestre du Quaternaire supérieur, dans le nord-ouest de l'île de Baffin, Territoires du Nord-Ouest.* On a procédé à l'analyse des données paléoenvironnementales tirées de sédiments terrestres, marins et lacustres, près de Arctic Bay. Dix-huit nouvelles dates au radiocarbone ont permis d'établir une nouvelle chronologie. Les dates les plus anciennes, et les moins fiables, ont été obtenus dans des tourbes sableuses et des sédiments lacustres à basse teneur organique. Les dates les plus sûres proviennent de coquillages marins et des foraminifères. Elles indiquent que la déglaciation était en cours dès 9000 BP plutôt qu'à 16 000 BP. Pendant la période relevée, l'environnement dans le haut Arctique était caractérisé au niveau local par un assemblage pollinique dominé par l'herbe, le carex et le saule; à l'Holocène moyen, les valeurs croissantes du saule, de l'herbe et de la mousse reflètent une période chaude. La densité de la glace marine était assez forte pour empêcher la croissance des diatomées jusqu'à 6300 BP; la déglaciation s'est poursuivie jusque vers 6000 BP dans les fjords. La reproduction des diatomées a augmenté entre 3000 et 2500 BP en raison de températures de surface plus chaudes et une diminution des glaces marines. Après 2000 BP, l'accumulation des diatomées a décru abruptement en raison d'un refroidissement climatique. Les foraminifères démontrent un changement important survenu dans l'état des eaux profondes vers 4000 BP puisqu'il y a eu remplacement des espèces benthoniques à test calcaire par des espèces à test agglutiné.

ZUSAMMENFASSUNG *Meeres- und Landumwelt im späten Quaternär im Nordwesten der Insel Baffin, Nordwest-Territorien.* Man hat Paläoumweltdaten von Erd-, See- und Meeres-Sedimenten analysiert, die man in der Nähe der Arctic Bay, Insel Baffin, Nordwest-Territorien gesammelt hat. Achtzehn neue Radiocarbondaten liefern eine chronologische Kontrolle und ersetzen so frühere Resultate. Falsche alte Daten hat man sowohl aus sandigem Torf wie auch aus Seesedimenten mit niedrigem organischem Gehalt gewonnen. Die zuverlässigsten Daten stammen von Meeresmuscheln und Foraminiferen. Sie zeigen, dass die Enteisung um 9000 v.u.Z. und nicht um 16,000 v.u.Z. im Gange war. Über den Zeitraum des Belegs charakterisierte sich die lokale Umwelt durch eine Pollen-Zusammensetzung der hohen Arktis, die von Gras, Schilfgras und Weide beherrscht war; auf eine warme Periode während des mittleren Holozäns weisen zunehmende Weiden-, Gras- und Mooswerte. Die Meereseisbedingungen waren streng genug, um das Wachstum von Diatomeen bis etwa 6300 v.u.Z. zu verhindern und Proximaleis und Enteisungsbedingungen herrschten in den Fjords bis etwa 6000 v.u.Z. vor. Die Reproduktion von Diatomeen nahm zwischen 3000 v.u.Z. und 2500 v.u.Z. zu, was auf wärmeres Oberflächenwasser und weniger Meereseis schliessen lässt. Nach 2000 v.u.Z. nahm die Diatomeen-Akkumulation wegen einer Klimaabkühlung plötzlich ab. Die Foraminiferen zeigen einen beträchtlichen Wechsel der Bedingungen im tiefen Wasser um etwa 4000 v.u.Z., wenn die benthonischen Spezies von einer kalkartigen zu einer sandigen Zusammensetzung übergehen.

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## INTRODUCTION

The area near the settlement of Arctic Bay, Baffin Island, N.W.T. (Fig. 1) is of interest because an organic-rich section located there provided $^{14}C$-dated evidence for terrestrial materials older than 11,000 BP and younger than 40,000 BP in the eastern Canadian Arctic (Short and Andrews, 1988). Because of the implications of these dates, we set up a sampling program to expand the data base by including lake and marine sediments, providing a link between terrestrial and marine paleoenvironments (Mudie, 1980, 1982; Mudie and Short, 1985; Short *et al.*, 1989) and to augment the chronological framework. In this paper, we present paleoenvironmental data from fiord and lake sediments and terrestrial organic-rich deposits located near the settlement of Arctic Bay, Baffin Island, N.W.T. (Fig. 1). The results of the expanded dating program suggest that great caution will have to be used in selection of material from this region for dating.

## SITE DESCRIPTION

Arctic Bay (Ikpiarjuk) is located between Arctic and Victor bays on Borden Peninsula, northwestern Baffin Island (Fig. 1). The low saddle in which the community lies is bordered on the west by the Uluksan Peninsula (456 m) and on the east by King George V Mountain (700 m).

The area is underlain by Precambrian and Paleozoic rocks. The dominant rock type is quartz arenite, although there are small outcrops of shale, limestone, and dolostone (Thorsteinsson and Tozer, 1970). Except in small wetlands and seepage slopes, regional vegetation cover is sparse. The local glacial history is not known in detail but mapping is progressing (A.S. Dyke, personal communication, 1992). At present small ice caps are located 70 km to the east and northeast of the settlement.

The region has a mean July temperature of 4.5°C, a mean annual temperature of − 14°C, and a mean annual precipitation of 15 cm (Maxwell, 1981); it lies in the southern part of the High Arctic terrestrial phytogeographic region (Polunin, 1960). The modern pollen spectra are dominated by local taxa, primarily *Salix* (willow), Gramineae (grass family), Filicales (ferns and fern allies), and Cyperaceae (sedge family) (Short and Andrews, 1988). Exotic pollen input is low (<200 grains/gram dry weight [g/gdw]). *Betula* (birch) is the most common exotic pollen type (0-9%) in the modern spectrum.

Strathcona Sound is normally covered by sea ice ten to eleven months of the year. Freeze-up usually occurs in early September, and the sound is not totally ice free until the first week of August. During exceptional years freeze-up may be delayed until the first week of October or the ice may not clear at all (Markham, 1981). The area is affected by the southward flow of Arctic Surface Water. Bottom water temperatures are probably about 0°C.

## COLLECTIONS AND METHODS

Three new organic-rich sections — Saddle Sections I and II and George V Section (Fig. 1) — were collected in 1987 for dating and fossil insect analyses. The section sampled in 1982 is discussed in detail in Short and Andrews (1988).

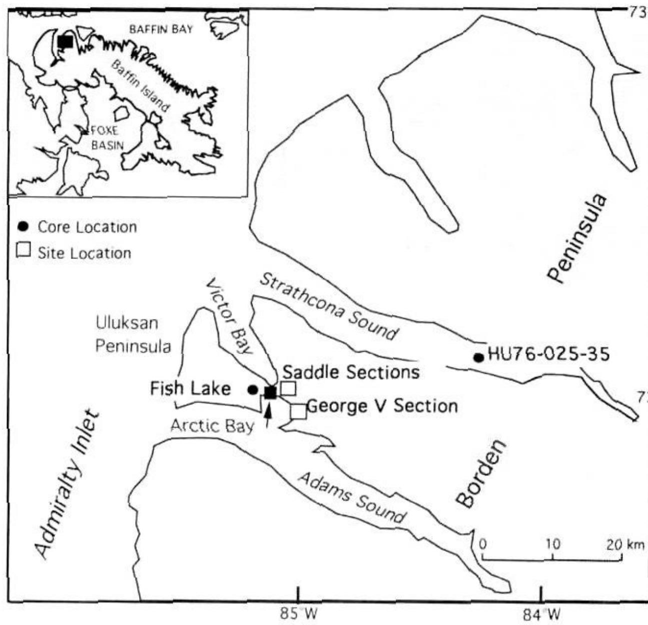



FIGURE 1. Site location map, Arctic Bay, Baffin Island.
*Carte de localisation d'Arctic Bay, dans l'île de Baffin.*

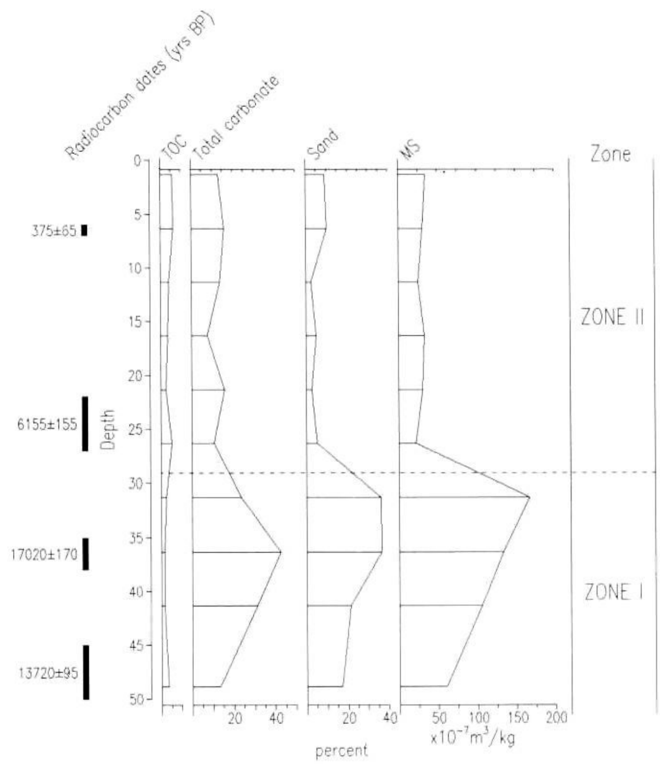
Three short (0.5 m) cores were collected using a raft and a piston corer at Fish Lake (73°02'05"N, 85°13'W, 91 m), Uluksan Peninsula (Fig. 1). This lake is small and shallow (*ca.* 8 m water depth at coring sites). Core 2 was analyzed for pollen (2-cm intervals), diatoms (10-cm intervals), sedimentology, and mass magnetic susceptibility (MS).

A 9.21 m-long piston core from a water depth of 230 m in Strathcona Sound (HU76-025-35) was analyzed for pollen, diatoms, sedimentology, and MS. Samples were processed at 35- and 50-cm intervals (to 9.03 m).

We used standard sedimentology techniques and diatom, foraminifera, fossil insect and pollen methods which have been described elsewhere (Jørgensen, 1967; Coope, 1968; Faegri and Iversen, 1975; Nichols, 1975; Cwynar *et al.*, 1979; Mudie, 1980; Williams, 1986; Andrews and Jennings, 1987; Jennings, 1989).

The pollen sum *excludes* pre-Quaternary palynomorphs and dinoflagellates, both of which are rare; thus, the former are not believed to affect the spurious radiocarbon dates. The pollen diagrams were constructed using a reduced data set (Figs. 2b, 3b).

Pollen concentrations are low in both the lacustrine and marine sediments. Total counts ranged from 40 to 100 pollen and spores, and two slides were frequently counted at each level in the marine core. These counts are comparable to those recorded in marine cores from central and northern Baffin Island fiords (Short *et al.*, 1989). The low pollen sums are of concern but can provide reliable environmental data if interpreted with care.




## RESULTS

### RADIOCARBON DATES

We have obtained 19 new $^{14}C$ dates from the Arctic Bay area in addition to the dates reported by Short and Andrews (1988) (Table I). Details on each new date are included in the data compilation of Kaufman and Williams (1992).

About half of these dates appear unacceptable, because of three major problems: (1) contamination of the acid-insoluble organic matter (AIOM) fraction in lake sediments with low organic carbon (*e.g.*, Clark *et al.*, 1989); (2) errors in the dates on the terrestrial peats; and (3) differences in the apparent ages of terrestrial and marine materials because of ocean residence time of $CO_2$ (Stuiver *et al.*, 1986).

The $^{14}C$ dates from Fish Lake 2 are on the AIOM fraction. The four dates have one age reversal, and the date from 6-7 cm (375 ±65 BP; AA-3997) appears "young" relative to that from 22-27 cm (6155±155 BP; AA-3288). The total organic carbon (TOC) weight percentages vary between 0.1

FIGURE 2a. Selected sedimentological parameters, Fish Lake 2. MS = mass magnetic susceptibility; TOC% = percent total organic carbon.

*Paramètres sédimentologiques choisis, à Fish Lake 2. MS = susceptibilité magnétique; TOC% = pourcentage de carbone organique total.*

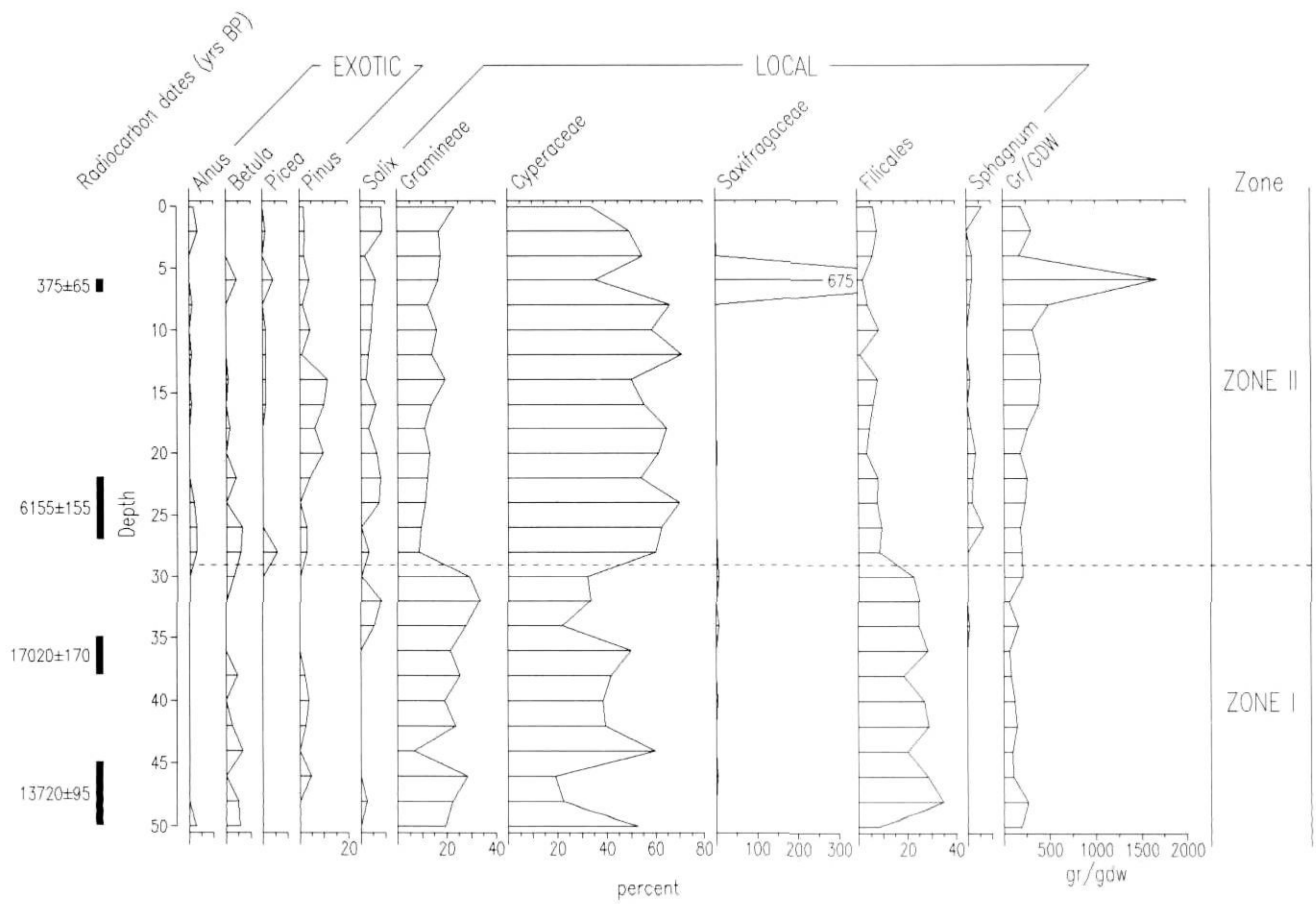



FIGURE 2b. Percentage pollen diagram (reduced data set) and pollen concentration summary (g/gdw), Fish Lake 2.

*Diagramme pollinique en pourcentage (ensemble réduit de données) et concentration pollinique totale (grains/g de séd. sec), Fish Lake 2.*

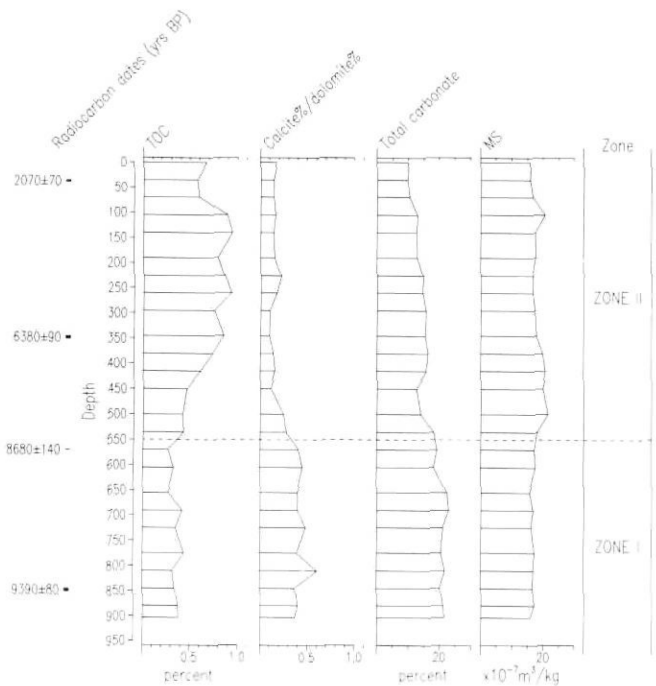



FIGURE 3a. Selected sedimentological parameters, HU76-025-35. MS = mass magnetic susceptibility; TOC% = percent total organic carbon.

*Paramètres sédimentologiques choisis, Fish Lake 2. MS = susceptibilité magnétique; TOC% = pourcentage de carbone organique total.*

and 5% (Fig. 2b). In these low-organic sediments, contamination of the AIOM fraction is possible from a variety of sources (Clark *et al.*, 1989; Short *et al.*, 1989), including black shales which occur locally in till (A.S. Dyke, personal communication, 1990). TOC dates on both marine and lacustrine sediments with low organic carbon content are now widely regarded as unreliable (Fillon *et al.*, 1981) and some laboratories (*e.g.*, GSC) will no longer date these materials. We believe that the Fish Lake dates are maximum ages and are thus suspicious.

The organic-rich sections have $^{14}C$ dates ranging from modern to 16,849± 860 BP (GX-9303) (Table I). Finite dates older than 10,000 BP were reported by Short and Andrews (1988) for the original section and also for Saddle Section II in this study. To test these results, we submitted macrofossils for AMS dating from the level dated 15,810 ± 490 BP (GX-10628) (Short and Andrews, 1988, Table II). The AMS result of 7790±65 BP (AA-3974) and other new dates (AA-6453 and GX-13795) (Table I) cast serious doubts on the validity of the > 10,000 BP dates.

The four marine carbonate dates have been adjusted for an ocean reservoir age of 450 years. Although a larger reservoir correction is possible, we use 450 years as a default value in line with earlier compilations from southern Baffin Island (see Kaufman and Williams, 1992). The shell date (GSC-5223) has a built-in correction of 410 years. Few calcareous foraminifera were recovered from the core top; therefore we used moss fragments to date this sediment. Because

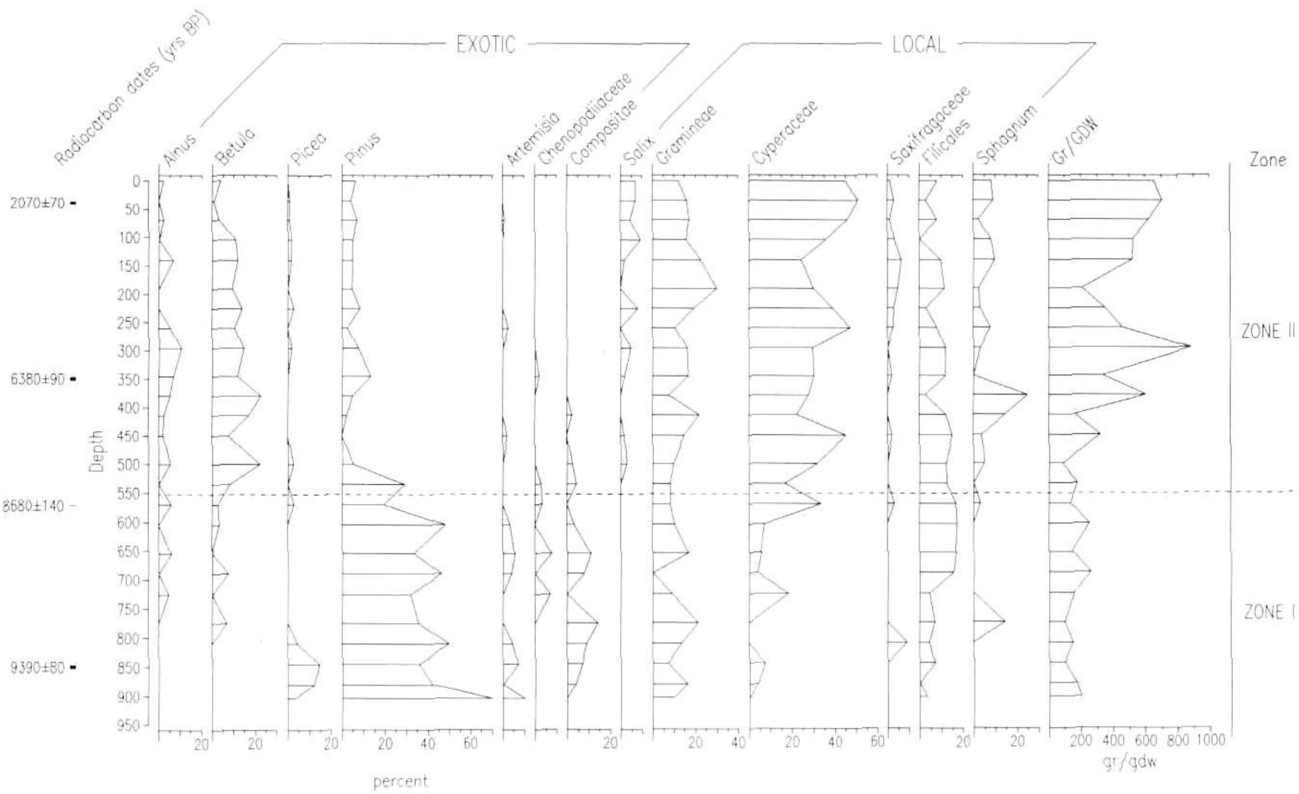



FIGURE 3b. Percentage pollen diagram (reduced data set) and pollen concentration summary (g/gdw), HU76-025-35.

*Diagramme pollinique en pourcentage (ensemble de données réduit) et concentration pollinique totale (grains/g de séd. sec), HU76-025-35.*

TABLE I

*Radiocarbon dates and sample data, Arctic Bay, Baffin Island*

| Site | Depth (cm) | Field no. | Sed lab no. | Material dated | Dated sample wt. (g) | % Organic carbon | pH | Radiocarbon age (yr BP) | "Corrected" date | Lab no.** |
|---|---|---|---|---|---|---|---|---|---|---|
| Strathcona Sd. | 35-39 | | CHEM#327 | Moss fragments | NA | NA | NA | 2070 ± 70 | 1620 ± 70 | AA-7012 |
| | 345-351 | | GRL-921-S | Foraminifera | 0.03 | NA | NA | 6380 ± 90 | 5930 ± 90 | AA-5290 |
| | 570 | | GRL-858-S | Shells | 0.134 | 0.85 | 8.1 | 8630 ± 140 | 8180 ± 140 | AA-2641 |
| | 845-851 | | GRL-922-S | Foraminifera, benthics | 0.01 | 0.27 | 8.5 | 9380 ± 80 | NA | AA-5987 |
| Victor Bay | | | | *Hiatella arctica* | 8.4 | NA | NA | 8600 ± 160 | 8630 ± 160 | GSC-5223 |
| Fish Lake 2 | 6-7 | FL2-4 | GRL-801-0 | Moss in clay | 0.09 | 5 | 7.3 | 375 ± 65 | NA | AA-3997 |
| | 22-27 | FL2-2 | GRL-786-0 | Clayey mud | 0.43 | NA | 6.9 | 6155 ± 155 | NA | AA-3286 |
| | 35-38 | FL2-3 | GRL-802-0 | Clayey mud | 0.09 | 1.92 | 7.1 | 17,020 ± 170* | NA | AA-3995 |
| | 45-50 | FL2-1 | GRL-773-0 | Clay | 0.31 | 2.99 | 7.1 | 13,720 ± 95* | NA | AA-3256 |
| Saddle Section I | 26-30 | I-1 | — | Sandy sedge peat | NA | NA | NA | 8770 ± 260 | NA | GX-13794 |
| | 60-63 | I-2 | — | Sandy sedge-sphagnum peat | NA | NA | NA | 7685 ± 260 | NA | GX-13795 |
| Saddle Section II | 23-27 | II-1 | — | Clay | NA | NA | NA | 9715 ± 380* | NA | GX-13796 |
| | 190 | II-2 | — | Sedge peat | NA | NA | NA | 10,595 ± 380* | NA | GX-13797 |
| | 435-440 | II-3 | — | Sedge peat | NA | NA | NA | 12,720 ± 670* | NA | GX-13798 |
| | 420 | II-4 | GRL-904-0 | Twig | NA | NA | NA | 7800 ± 70 | NA | AA-6453 |
| George V Section | 85-90 | GV-1 | — | Sandy sedge peat | NA | NA | NA | 6770 ± 205 | NA | GX-13799 |
| | 163-166 | GV-2 | — | Sedge peat | NA | NA | NA | 8460 ± 245 | NA | GX-13800 |
| | Slump "B" | GV-3 | — | Sedge peat | NA | NA | NA | 7730 ± 180 | NA | GX-13801 |
| 1982 Organic | 0-4 | AB-5 | GRL-615-0 | | 4.06 | 10.5 | 3.3 | Modern | NA | GX-9685 |
| Section | 23-26 | AB-4 | GRL-616-0 | | 0.8 | 20.4 | 4.3 | 5075 ± 210 | NA | GX-9686 |
| | 50-57.5 | AB-8 | GRL-717-0 | Sedge peat | 3.16 | NA | NA | 6720 ± 390 | NA | GX-12852 |
| | 82.5-87.5 | AB-1 | GRL-587-0 | | 2.52 | 8.4 | NA | 8635 ± 565 | NA | GX-9302 |
| | 137.5-142.5 | AB-7 | — | Sedge peat | NA | NA | NA | 7830 ± 180 | NA | GX-10829 |
| | 182.5-187.5 | AB-2 | GRL-588-0 | | 0.63 | 2.5 | NA | 16,849 ± 860* | NA | GX-9303 |
| | 255-260 | AB-6 | GRL-670-0 | Sedge peat | 0.76 | 3.75 | 5.9 | 15,810 ± 490* | NA | GX-10628 |
| | 255-260 | AB-9 | GRL-800-0 | Plant fragments | NA | NA | NA | 7790 ± 65 | NA | AA-3974 |
| | 280-290 | AB-3 | GRL-589-0 | | 0.54 | 4.3 | NA | 14,185 ± 760* | NA | GX-9304 |

* = Dates judged questionable on low terrestrial acid-insoluble organic matter.
** = AA dates are AMS dates; GX dates are standard dates.
NA = not applicable.

the upper sediment of the piston cores is often lost during collection, we assume an age for the top of the piston core of 500 ± years.

Our assessment of the $^{14}C$ dates we have obtained is that we place most reliance on AMS dates on plant macrofossils or on marine carbonates. Both conventional and AMS dates on organic-poor sediments appear to be contaminated by old carbon, probably from erosion of the surrounding shales.

## LAKE SEDIMENTS

### Sedimentology

Fish Lake cores 2 and 4 were X-radiographed and their volume magnetic mass susceptibility determined. The cores had zones of laminae. Figure 2a shows the downcore variations in some selected variables (TOC, total carbonate, sand, and MS) for Fish Lake 2. The sediments range from sandy silt to clayey silt. They are moderately compact; dry volume densities commonly range from 600 and 800 kg/m$^3$. The total carbonate (largely dolomite), sand percentage, and magnetic mass susceptibility show pronounced peaks between *ca.* 30 and 45 cm.

### Pollen

Two pollen zones are defined:

*Zone I (50-30 cm)*. Low pollen concentrations are characteristic of this zone, commonly ≤2000 g/gdw (Fig. 2b), and the most abundant taxa are Cyperaceae, Gramineae, and Filicales. The percentage pollen spectrum (Fig. 2b) is also dominated by Gramineae (generally ≥20%), Filicales (generally ≥20%), and Cyperaceae (19-60%). *Salix* is only sporadically represented, *Alnus* is recorded at only one level, and no

*Picea* pollen grains are recorded. *Betula* and *Pinus* occur consistently in the lower half of the zone.

*Zone II (30-0 cm)*. Pollen concentrations (Fig. 2b) commonly range between 2000 and 4000 g/gdw, with a prominent peak of 16,790 g/gdw at 6-cm dominated by *Saxifraga oppositifolia* (purple saxifrage; 14,626 g/gdw).

Cyperaceae (*ca*. 60%), Gramineae (10-20%), and Filicales (≤8%) continue to dominate the percentage pollen assemblage (Fig. 2b), but the latter two have decreased in abundance. *Salix, Pinus*, and various herb pollen taxa are recorded throughout the zone. *Alnus, Betula*, and *Picea* occur sporadically. The large value of *Saxifraga oppositifolia* at the 6-cm level (675%, excluded from the pollen sum at this level *only*) highlights the potential problem of overrepresentation of one or two taxa in a low-productivity environment.

### Diatoms

Except for rare fragments of *Fragilaria* spp., the Fish Lake 2 core is barren of diatoms. We suspect that the lake water has a high pH (>8) because of the high carbonate content of the sediment (Fig. 2a), which would cause the diatom frustules to dissolve.

## MARINE SEDIMENTS

### Sedimentology

The sediment in HU76-025-35 is reddish to dark grey colour and coarsens upward from the base. Ice rafted pebbles occur throughout. Gravel-size carbonate particles occur below 540 cm. The fine-grained sediments suggest that deposition resulted from settling of suspended sediment contained in glacial or nival meltwaters (Gilbert, 1982; Hein and Longstaffe, 1985; Andrews, 1990). Rare thin-bedded sands indicate possible deposition from turbidity currents (Hein and Longstaffe, 1985).

There are two distinct sedimentary units that reflect both a change in sedimentation rate and a shift in provenance, with the boundary at about the 550 cm level (Fig. 3a). The TOC in the lower unit ranges from 0.2% to 0.4%, whereas in the upper unit it ranges from 0.55% to 1.0%. Conversely, the carbonate content and the ratio of calcite to dolomite decrease from the base to the top, with a hint of a step change at the boundary.

### Pollen

Two pollen zones are defined:

*Zone I (500-903 cm)*. Pollen concentrations are low (<250 g/gdw) in Zone I (Fig. 3b) and dominated by *Pinus*. Exotic taxa, especially *Pinus* (19-70%), *Picea* (4-14%), *Betula* (3-14%), *Artemisia* (sage; 0-6%), Compositae (sunflower family; 0-14%), and Chenopodiaceae (goosefoot family; 0-8%), dominate the percentage pollen assemblage (Fig. 3b). *Alnus* is present sporadically. Filicales rises in the upper part of Zone I and peak values (11-18%) persist into Zone II.

*Zone II (0-500 cm)*. Zone II is distinguished by larger pollen concentrations, generally >400 g/gdw (Fig. 3b). The pollen concentration spectrum is dominated by Cyperaceae and Gramineae, with maximum numbers of *Alnus* and *Betula*. The percentage pollen spectrum (Fig. 3b) is also dominated by Cyperaceae (22-51%), Gramineae (10-30%), *Betula* (1-23%), and *Alnus* (0-10%). Other exotic taxa (*e.g.*, *Pinus*, *Artemisia*, Compositae, and Chenopodiaceae) decline rapidly at the zone boundary. *Betula* percentages decrease in the upper 70 cm. Several local taxa, *e.g. Salix* and *Sphagnum*, are consistently present in the upper two-thirds of the zone.

### Diatoms

Diatoms are present from *ca*. 400 cm to the top of the core (Fig. 4a). They peak in abundance at 105 cm, followed by a

TABLE II

*Fossil insect and arthropod remains, Saddle I, Arctic Bay*

| Depth (cm) | 0-5 | 5-10 | 10-15 | 15-20 | 20-25 | 25-30 | 30-35 | 35-40 | 40-45 | 45-51 | 51-57 | 60-63 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oribatid Mites | 49 | | | | | 3 | 13 | 9 | 9 | 8 | 1 | 5 |
| Spiders | | | | | | 2 | | 6 | 4 | 1 | | |
| Fly Puparum | | | | | | | | 1 | 1 | | | |
| Caddisflies | | | | | | | | | | 1 | | |
| Parasitic Hymenoptera | | | | | | | | | | | | 1 |
| Aleocharinae | | | | | | | | | | | 1 | |
| *Hydroporus* sp. | | | | | | | | 1 | | | | |
| *Pterostichus (Cryobius)* sp. | | | | | | | | | 1 | | | 1 |
| *Amara alpina* Zett. | | | | | | | | | 1 | 1 | | |
| Carabidae undet. | | | | | | | | 1 | | | | |
| Total | 49 | 0 | 0 | 0 | 0 | 5 | 13 | 18 | 16 | 11 | 2 | 7 |

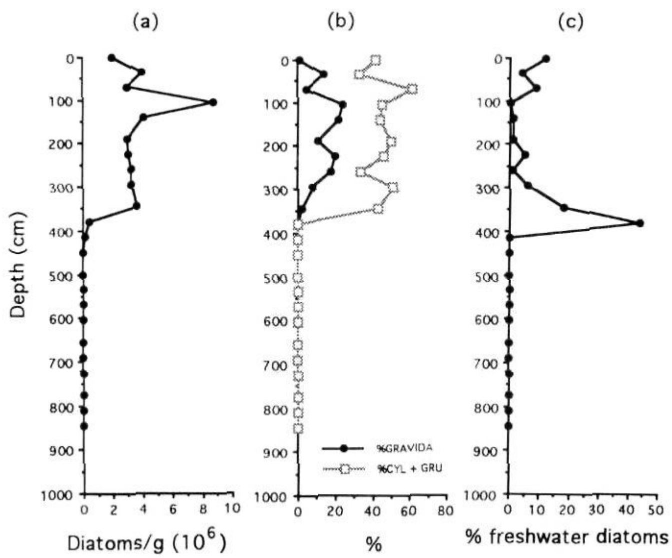



FIGURE 4. Selected diatom variables, HU76-025-35: a) total number of diatoms per gram versus depth; b) % *T. gravida* and % *N. cylindra* + % *N. grunowii*; c) % freshwater diatoms.

*Variables diatomiques choisies, HU76-025-35: a) nombre total de diatomées par gramme sur la profondeur; b) % de* T. gravida *et % de* N. cylindra + % *de* N. grunowii; *c) % de diatomées d'eau douce.*

low at 70 cm. Freshwater diatoms appear in the core at the beginning of the diatom record (Fig. 4c), marking an influx of fresh water from the land. Subsequently, the record shows a reduced input of freshwater diatoms, relative to marine taxa, between 350 cm and 100 cm. A renewed influx of freshwater diatoms occurs above 70 cm. Increased terrestrial input into the fiord at that time is supported by abundant fragments of mosses and liverworts (M. Walker, personal communication, 1991) in the sediment.

*Nitzschia grunowii* and *N. cylindra,* sea-ice indicators (Sancetta, 1982; Williams, 1986), as well as *Thalassiosira gravida*, a species tolerant of generally cold, relatively low salinity conditions (*e.g.*, meltwater influence), are well represented in the core (Fig. 4b). *N. grunowii* and *N. cylindra* peak around 70 cm, a time of decreased diatom productivity, suggesting a greater severity of pack ice.

Foraminifera

The Strathcona Sound core has low numbers (1-50/g) and few species of foraminifera. A screen size of 63 μm was used in this study. Planktonic forms, represented only by *Neogloboquadrina pachyderma*, are rare throughout (< 4% of total calcareous foraminifera). *Cassidulina reniforme* (Fig. 5), a component of the "ice distal facies" (Osterman, 1982), is most abundant below 500 cm, and makes up over 80% of the calcareous fauna below 700 cm. *Islandiella norcrossi* (Fig. 5), a component of the "extreme ice distal facies" (Osterman, 1982), is most abundant in the top 500 cm, constituting more than 50% of the calcareous forms above 350 cm. *Elphidium excavatum clavata* (Fig. 5), an "ice proximal-extreme ice proximal species" (Osterman, 1982), is present below about 200 cm, but never comprises more than 10 % of the fauna. *Fursenkoina fusiformis*, a species associated with ice distal glacial marine and ice margin sediments (Scott *et al.*, 1984; Vilks *et al.*, 1989; Evans, 1990), is uncommon but increases in abundance downcore to a maximum of 12% at the base (Fig. 5). *Buccella frigida* is present above 400 cm; this species is characteristic of water temperatures and salinities in the ranges of 0-2°C and 33-34 % (Vilks and Deonarire, 1988). Thus, the foraminifera indicate that the ice margin retreated from this area during the time the sediments in the core were being deposited.

The top of the core has a distinctive agglutinated fauna (Fig. 5), dominated by *Adercotryma glomerata* and *Spiroplectammina biformis*. The modern distribution of live agglutinated and calcareous species appears to be controlled by differences in water masses, *e.g.* temperature, salinity, ice cover, availability of calcium carbonate (Vilks, 1969; Greiner, 1974; MacLean *et al.*, 1989; Hunt and Corliss, 1993). Agglutinated faunas record a broad regional signal and the establishment of modern oceanographic conditions — *i.e.*, cold, less saline Arctic waters — after 6000 BP in many sites. On the northern and central Baffin Shelf, the replacement of calcareous foraminifera by arenaceous foraminifera after 6000 BP is believed to correspond to the re-establishment of the $CO_2$-rich Baffin Current (Osterman and Nelson, 1989). These faunas are also associated with modern currents on the Labrador-Newfoundland-Nova Scotia shelf (Miller *et al.*, 1982; Scott *et al.*, 1984; Vilks *et al.*, 1984; Williamson, 1985).

*Cibicides lobatulus*, a calcareous encrusting species, constitutes 10-17% of the calcareous foraminifera in the upper 35 cm of the core (Fig. 5); it is also associated with modern currents.

ORGANIC SECTIONS

Fossil insects

George V Section is barren of insect remains and Saddle Section I contains infrequent insect and arthropod fossils (Table II). The record is dominated by oribatid mites and spiders; beetle remains are rare. Only modern water beetles (Dytiscidae) were successfully collected during the 1987 field season. We believe the Arctic Bay region is at the northern limit of beetles' and many other insects' ranges, probably because of the aridity of the area.

## DISCUSSION

CHRONOLOGY

We now have 27 radiocarbon dates on terrestrial and marine sediments from Arctic Bay and Strathcona Sound. We believe that none of the dates older than 9000 BP, the probable date on deglaciation of the area, are reliable. They must be treated with caution until we can explain the differences

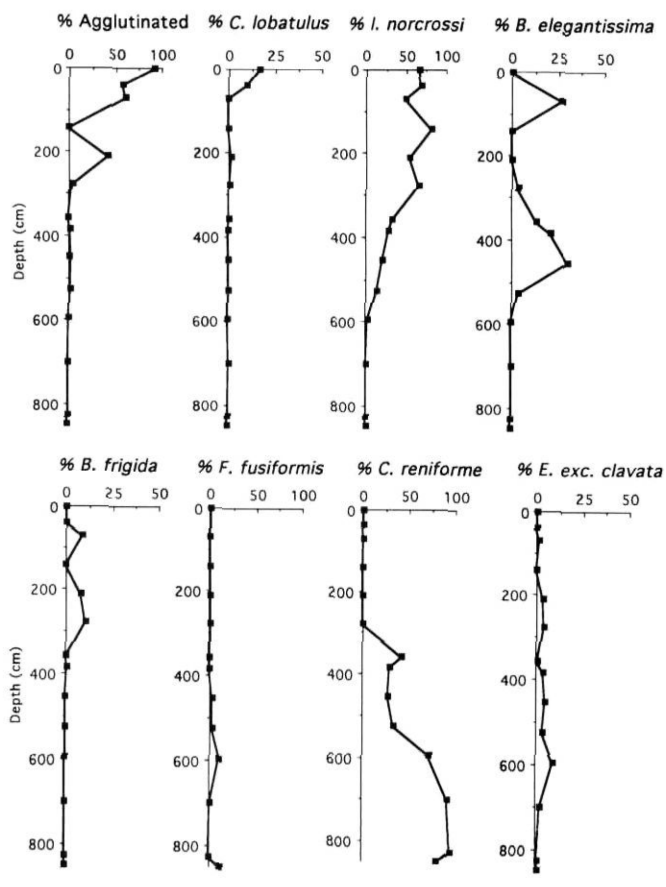



FIGURE 5. Percentage foraminifera diagram, HU76-025-35.
*Diagramme des foraminifères en pourcentage, HU76-025-35.*

between paired dates from the same level (*e.g.* GX-10628 and AA-3974) (Table I).

The existing regional chronology supports our estimate of the timing of deglaciation. Radiocarbon dates from shell and whalebone indicate that seasonally open water was present to the west (Dyke, 1984; Dyke and Morris, 1990; MacLean *et al.*, 1989) by about 9500 BP and to the east by about 9400 BP (Klassen, 1985), coincident with the retreat of the Laurentide Ice Sheet from the southern arctic channels (Dyke and Prest, 1987; MacLean *et al.*, 1989). Late Foxe ice margin features around Arctic Bay are well-defined (A.S. Dyke, personal communication, 1990), and the marine limit (60 ± 10 m) is dated 8630 ± 160 BP (GSC-5223) (normalized to 0‰ $\partial^{13}C$) based on a shell sample collected by Short in 1987. These shells came from a glaciomarine delta on the east side of Victor Bay (Fig. 1). At the time the delta was forming, the terrestrial sites at the Saddle and King George V Mountain were still ice covered and Fish Lake must have been just recently deglaciated (A.S. Dyke, personal communication, 1993).

## TERRESTRIAL VEGETATION HISTORY

The terrestrial environment of the Arctic Bay region has been characterized by a high arctic assemblage dominated by grass, sedge, and willow since deglaciation (Fig. 6). Dating control for the terrestrial record is admittedly poor; we assume a date for the base of the core of 9000 ± BP. Grass and ferns were dominant elements of the local vegetation in the early postglacial period, but low pollen concentrations and high exotic pollen influx suggest that the vegetation at this time was very sparse. Locally there was a major increase in pollen concentration values and a vegetation change to a sedge-grass dominated terrestrial environment dating to *ca.* 7000 BP. Willow shrubs, *Sphagnum* moss, and various herb taxa were more consistently represented in the vegetation shortly thereafter. Previously we proposed that this pollen spectrum represented a local climatic optimum in northwestern Baffin Island (Short and Andrews, 1988).

This vegetation history is supported by the Strathcona Sound core, which has a lower assemblage (pre-7800 BP) dominated by exotic pollen, suggesting a sparse local vegetation, and an upper assemblage representative of the present vegetation. The bipartite pattern is also similar to the pollen stratigraphy of five marine cores from eastern Baffin Island (Short et *al.*, 1989). There is no evidence in the local vegetation record of major change in the late Holocene.

## EXOTIC POLLEN

Exotic pollen are an important component of both the terrestrial and marine pollen spectra. Previous studies have demonstrated that long-distance eolian transport of pollen is common in the Arctic (Lichti-Federovich, 1974; Nichols *et al.*, 1978; McAndrews, 1984; Bourgeois *et al.*, 1985; Fredskild, 1985; Short and Holdsworth, 1985; Bourgeois, 1986).

Peak exotic pollen are registered in the lower sections of both records (Fig. 6). This influx of exotic pollen occurred before the breakup of the Laurentide Ice Sheet and before the establishment of modern vegetation ranges. We interpret the influx of exotic birch and pine pollen in the basal levels of the terrestrial record to register the frequent advective transport

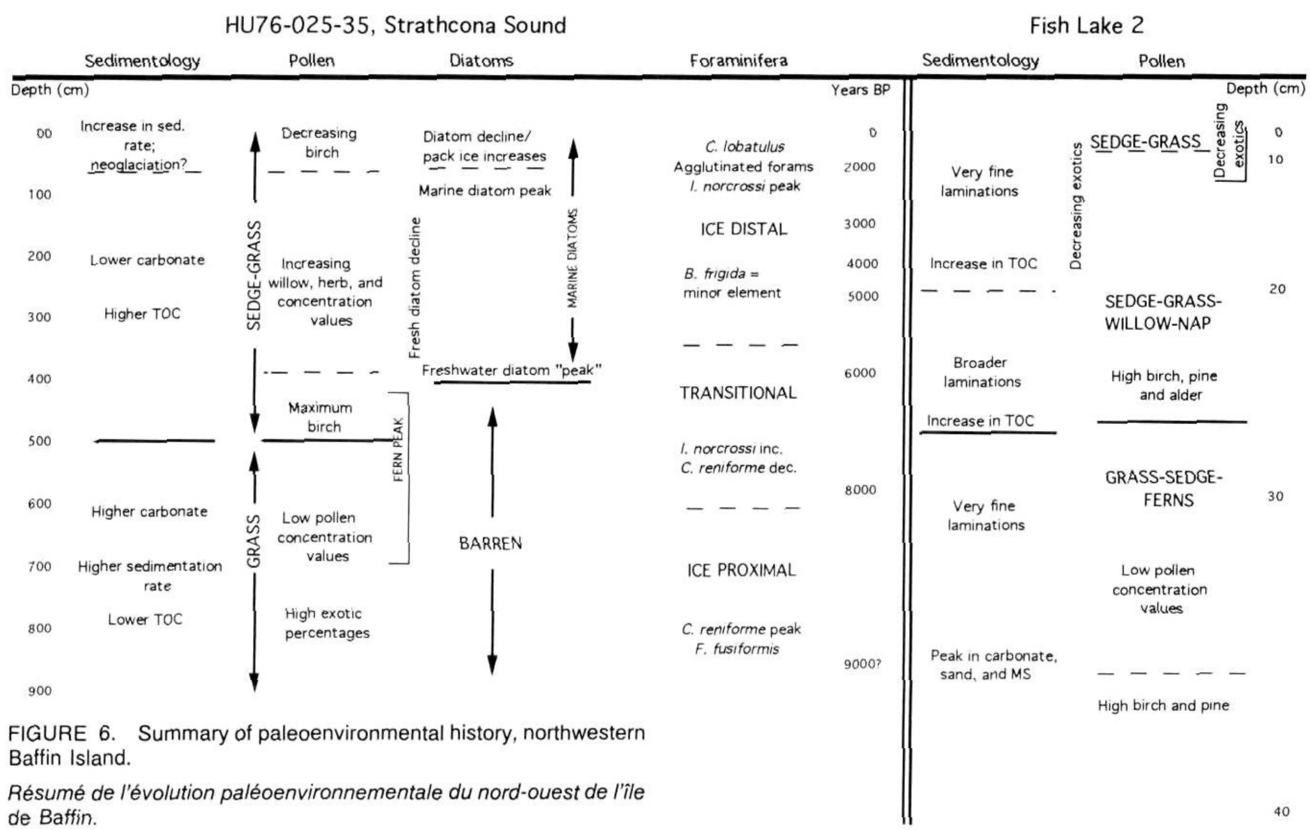



FIGURE 6. Summary of paleoenvironmental history, northwestern Baffin Island.

*Résumé de l'évolution paléoenvironnementale du nord-ouest de l'île de Baffin.*

of these grains from southerly or westerly sources onto the impoverished local vegetation. Pollen can enter a fiord system in several ways, including fluvial, eolian, and marine transport (Short *et al.*, 1989). Hence, the interpretation of the exotic pollen spectrum in the lower part of core HU76-025-35 (*i.e.*, between *ca.* 8600 and 9400 BP) is more indeterminate.

Increased exotic pollen influx into the region after *ca.* 7000 BP reflects the establishment of more continuous vegetation cover to the south and west. In the terrestrial record, alder and spruce appear consistently for the first time. Both Fish Lake 2 and HU76-025-35 register peak birch influx in the middle Holocene. Decreasing birch influx in the latest Holocene (Fig. 6) records increasingly impoverished conditions in southern Baffin Island (Mode, 1980; Short *et al.*, 1985).

## MARINE DEPOSITIONAL HISTORY

On Figure 7 we compare the ln (1/TOC%), which reflects relative changes in the rates of clastic sedimentation, and diatom accumulation rates (g/cm$^2$/yr(10$^6$)) for the Strathcona Sound core. Andrews (1987) and Syvitski *et al.* (1990) showed that the amount of total organic carbon in sediments in Baffin Island fiords is inversely related to the rate of sedimentation. The two records are partial mirror images, and allow us to divide the core into four zones.

Zone A (9000-6300 BP) is barren of diatoms and sedimentation rates are high. There is an increase in the sedimentation rate immediately prior to 8180 ± 140 BP (AA-2641, corrected) which may coincide with local Cockburn glacial re-advances on northern Baffin Island (Falconer *et al.*, 1965). The lack of diatoms indicates severe ice conditions in the fiord. Pollen, mainly exotic, settled on the sea-ice surface, and during the summer the sea ice probably broke up sufficiently for pollen and other wind- and fluvially-deposited particles to drop into the sea. The foraminifera indicate ice proximal conditions at the beginning of the record, but the change to a transitional assemblage by 8000 BP suggests retreat of land-based ice masses.

The lower boundary of Zone B (6300-3500 BP) marks the sudden increase in diatom accumulation rates and a change to lower sedimentation rates. The peak percentage of freshwater diatoms at 6300 BP suggests an abrupt influx of water from terrestrial sources at that time. This suggests a warming of the land areas around Strathcona Sound, allowing the lakes and ponds to develop diatom blooms. These diatoms were then flushed into the sea during spring melt, either as part of the sediment thanatocoenoses or as living cells. Marine diatoms appear suddenly in the Strathcona Sound record around 6000 BP. There may be several reasons for these sudden changes. In response to increasing regional warming, the sea could have developed an ice-free area around the perimeter of the Sound during the summer months where marine diatoms flourished. Alternatively, sea ice concentration may have lessened during the summer, allowing increased diatom bloom. The large percentages of the sea-ice indicators, *N. grunowii* and *N. cylindra* (Fig. 4b), around 6000 BP suggests that sea ice concentrations/densities were high (*e.g.*, Williams, 1990). The foraminifera

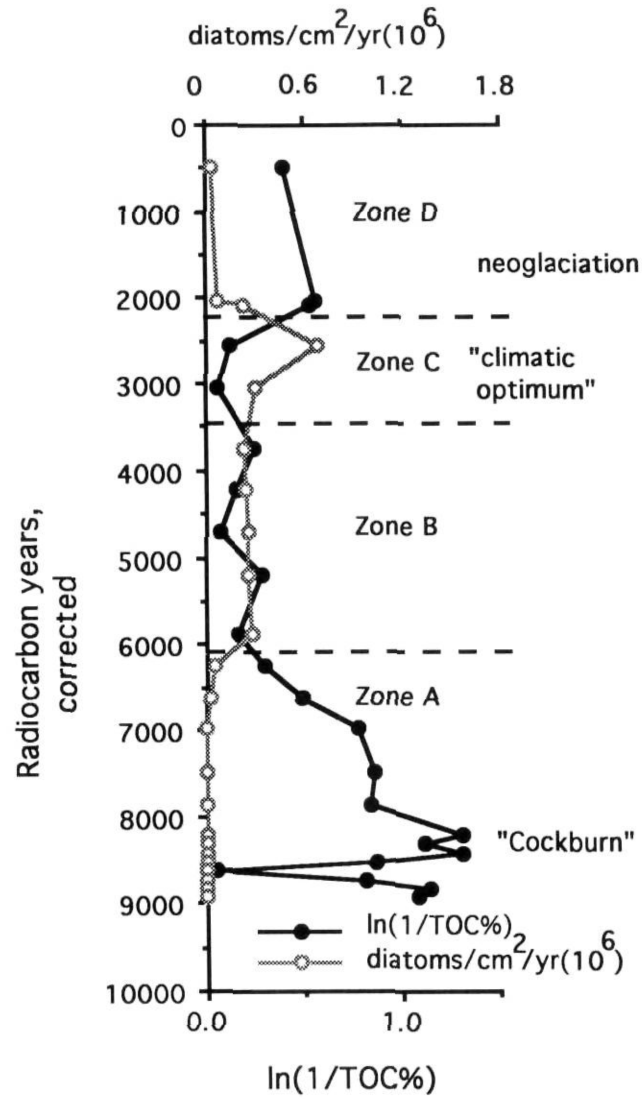



FIGURE 7. Diatom accumulation rates, ln (1/TOC%), and some paleoenvironmental events, HU76-025-35.

*Les taux d'accumulation des diatomées selon les événements paléoenvironnementaux, HU76-025-35.*

are dominated by ice distal species during this period. Thus, from 6000 BP to *ca.* 3500 BP the oceanographic conditions in Strathcona Sound did not vary a great deal.

Zone C (3500-2100 BP) registers an increase in diatom accumulation rates. At the same time, sea-ice indicators also decrease (Fig. 4b). These patterns suggest a warming of surface water and a concomitant lessening of sea-ice concentration. Sedimentation rates reach their lowest values at this time. The rise in agglutinated foraminifera *ca.* 4000 BP marks the establishment of modern oceanographic conditions, *i.e.*, the fauna are no longer responding to a glacial/terrestrial signal but to a regional oceanographic/marine signal.

A cooling of the sea surface is suggested by lower diatom accumulation rates and an increase in sea-ice indicators (Fig. 4b) in Zone D (2100-500 BP). Sedimentation rates rise toward the top of the core, possibly associated with the growth of local glaciers and ice fields during the neoglacial interval (Andrews, 1982; Davis, 1985).

## CONCLUSIONS

1. There are inconsistencies in the radiocarbon dates >10,000 BP, but 9000 BP is a reasonable estimate on the timing of deglaciation in the Arctic Bay region. Conventional radiocarbon dates on organic sediments give ages that are too old in comparison to AMS dates. However, AMS dates also yield spuriously old results for lake sediments with low organic contents. Presently, the most reliable ages are conventional and AMS dates on marine shells, foraminifera, and plant macrofossils.

2. During the early Holocene, the local terrestrial vegetation, dominated by grasses and sedges, was sparse, allowing an influx of exotic tree and shrub pollen from south and west of the ice sheet to dominate the local pollen rain. Ice proximal and deglacial conditions existed in Strathcona Sound, but sea-ice densities inhibited diatom growth until *ca.* 6300 BP.

3. The local pollen record registers a middle Holocene warming after ca. 7000 BP and intensifying after shortly thereafter, while the exotic pollen record reflects the development of forest to the south and west during the same interval. A peak in diatom productivity between 3500 and 2500 BP is thought to record warmer surface waters and less summer sea ice, while the establishment of agglutinated foraminifera, *B. frigida*, and peak *I. norcrossi* percentages indicate the establishment of modern bottom water conditions in the fiords. There is a similar offset between the pollen "climatic optimum" and the diatom "climatic optimum" along the eastern Baffin Island coast (see Williams, 1990) as the terrestrial and marine environments are reacting to different forcing factors.

4. A decline in diatom productivity and increased sedimentation in the marine cores after 2000 BP is correlated with a climatic cooling evidenced by more sea ice and perhaps neoglaciation on land. Although the local vegetation record is complacent in the late Holocene, the decline in birch influx at this time can be related to cooler climate in southern Baffin Island.

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